

Intro to Public Safety Broadband – LTE in the 700 MHz band

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A decorative graphic element consisting of a thick, black, wavy line that starts on the left side of the slide, dips down, and then rises towards the right, creating a stylized horizon or ground effect.

Public Safety Communications

- ▶ What types of communications does public safety require?

- Dispatch and tactical operations
 - Conventional radio systems
 - Trunked radio systems (analog & digital)
- Data
 - Mobile Data Terminals (MDTs)
 - PDAs/Smart phones

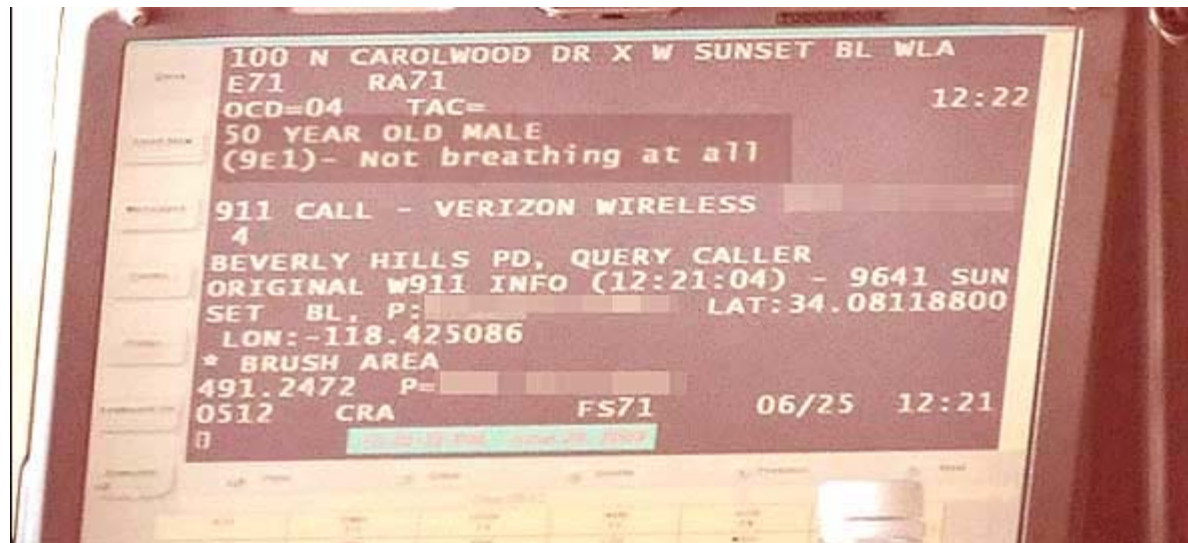


Data Requirements

- ▶ Today public safety data systems are used for:
 - Dispatch
 - Address/location, additional information, incident details
 - Database access
 - Records Management System (RMS)
 - Law Enforcement Information Portal (LEIP)
 - Police Information Portal (PIP)
 - National Crime Information Center (NCIC)
 - Canadian Police Information Center (CPIC)
 - DMV inquiries/Vehicle license checks
 - etc.
 - Short messaging

Example MDT Screenshot

- ▶ Michael Jackson's 9-1-1 call on an MDT screen in a rescue vehicle:



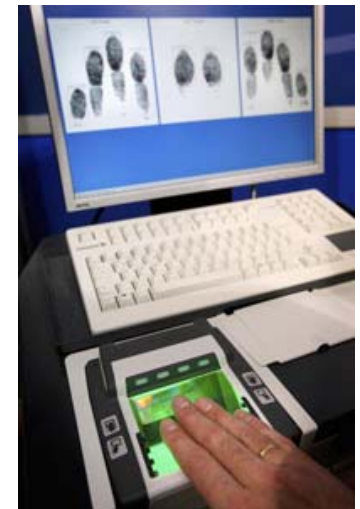
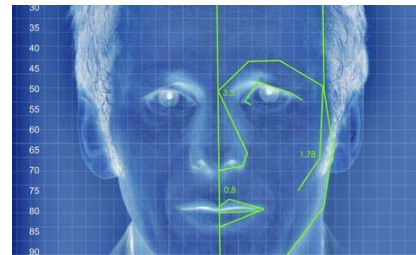
Characteristics of today's public safety data systems

- ▶ Older systems → Data rates up to 96 kbps, maybe 230 kbps using wideband technology
- ▶ May make use of private radio network, or public cellular data networks (e.g., GPRS), WiFi, or WiMAX (Clear)
 - 2 Mbps to 14 Mbps down, 0.8 Mbps to 2 Mbps up
 - HSPA 3.6Mbps to 7.3 Mbps
 - WiMAX 3–6 Mbps
- ▶ Commercial wireless networks offer a quick, simple and inexpensive mobile data solution for large and small agencies
 - Agencies have deployed Blackberry or similar wireless PDA devices to allow transmission of text information to key personnel either via paging or e-mail.

However

New Services Demand Higher Data Rates

- ▶ Photos
- ▶ Graphics
- ▶ Videos
- ▶ EMS Telemetry & Video
- ▶ Fingerprint Scanning
- ▶ Facial Recognition
- ▶ Location/tracking
- ▶ Firefighter Monitoring



A Look at Services ...

Law Enforcement

- ▶ Fingerprint Scanning – live fingerprint scanning using a technology certified by the Federal Bureau of Investigation as compatible with IAFIS (Integrated Automated Fingerprint Identification System). This would be a positive method of identification during field interrogation stops.
- ▶ Facial Recognition – this technology transmits a photograph from a digital camera to a data hub and runs it against a database using facial recognition software. A motion camera could capture multiple faces in a crowd and the public safety network would have the bandwidth to transmit this snapshot video to a data hub for comparison. The application could scan a crowd for a single person.
- ▶ License Plate Recognition – a camera captures license plates and transmits the image to software that reads them and matches the data against stolen vehicle or sex offender files.
- ▶ License Tag Checks – the predominant use of wireless data today involves inputting the tag number into the mobile data terminal and checking it against stolen files, wants and warrants against owner/driver, unpaid parking tickets, etc.
- ▶ Driver's License Scan – rather than manually inputting data, such as name or date of birth, a scan could provide information obtained from a driver's license more quickly.
- ▶ National Crime Information Center/State Database Checks – very similar to license tag checks except one can use other qualified identifiers such as name, date of birth, serial number, etc.
- ▶ Streaming Video – law enforcement video currently records traffic stops and can be particularly effective for documenting offender demeanor in drunken driving cases. Today, this video is taken by a dash-mounted camera and recorded on a disk usually contained in the vehicle trunk. Streaming video would enable real-time monitoring of an evolving incident by the dispatcher and/or responding back up units. This capability could be expanded by decoupling the camera from the dash and having a device that was more deployable. Imagine a portable surveillance camera that could be placed and aimed and then would transmit continuous images of a location to vehicles blocks away or into a command center. SWAT applications such as helmet mounted cameras for shared tactical video are also possible.
- ▶ Location/Tracking – applications that would allow dispatchers to monitor the location of officers using GPS or other tracking technology embedded in the wireless device and display that information on an electronic pin map. This application would also benefit fire service.

A Look at Services (continued)

Fire Service

- ▶ Bulk Data Files – building and floor plans could be wirelessly transmitted to the field from a central data warehouse to facilitate decision making.
- ▶ Location/Tracking – similar to the law enforcement application, this feature could permit the monitoring of the location of firefighters using GPS or other tracking technology embedded in the wireless device and display that information on an electronic pin map.
- ▶ Streaming Video – similar to the law enforcement requirement but the transmission device needs to be customized to a firefighter's situation such as making it more, heat resistant, more ruggedized and with a larger and brighter screen. The application could be used to transmit data on the fire observed from the inside to outside commanders and could be used to transmit pictures of possible threats; e.g., hazardous materials stored in the burning building.
- ▶ Firefighter Individual Monitoring – sensor applications that detect heart rate, carbon dioxide levels, temperature, blood pressure, etc., could be transmitted from the individual firefighter working the fire to on-scene commanders.

A Look at Services (continued)

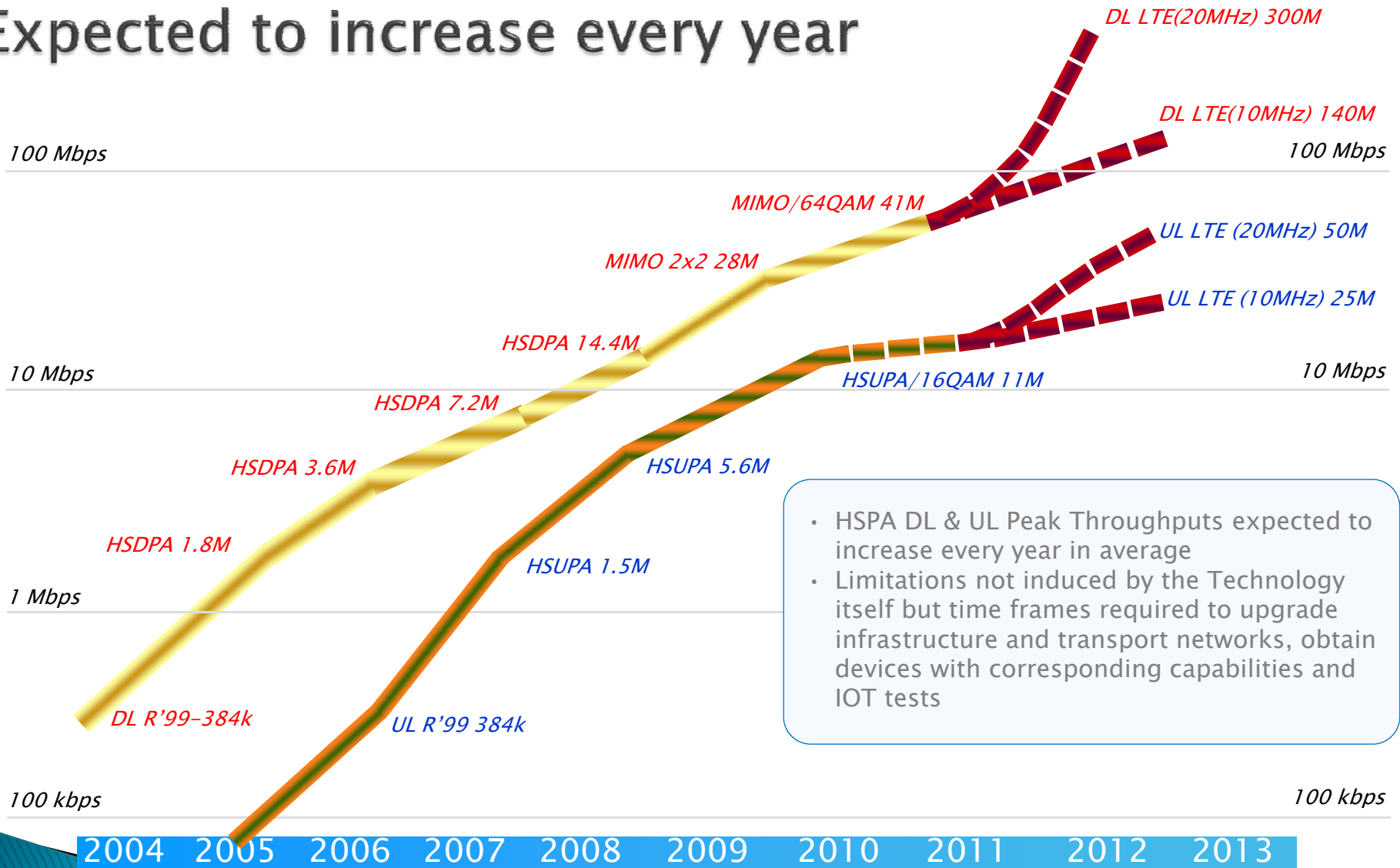
Emergency Medical Service

- ▶ Medical Telemetry – data could be transmitted continuously from an inbound emergency patient to the emergency room staff.
- ▶ Streaming Video – the ability to observe the patient visually while in transit to try to improve the level of emergency care.

All these new services have one thing in common

- ▶ The need for speed!!
- ▶ Broadband networks
- ▶ So where are the commercial networks heading?

HSPA/LTE Peak Throughput Evolution: Expected to increase every year



The Technology

- ▶ At its June 2009 meeting, the National Public-Safety Telecommunications Council (NPSTC) voted to endorse Long Term Evolution (LTE) as the technology of choice for the Nationwide Broadband Data System (NBDS)

NATIONAL PUBLIC SAFETY TELECOMMUNICATIONS COUNCIL



NPSTC

700 MHz Public Safety
Broadband Task Force
Report and
Recommendations

Chair David Buchanan

Operations Work Group Co-Chairs Dan Hawkins and David Troup
Technical Work Group Co-Chairs Andrew Thiessen and Emil Olbrich
Governance Work Group Co-Chairs Laura Phillips and Bill Schrier

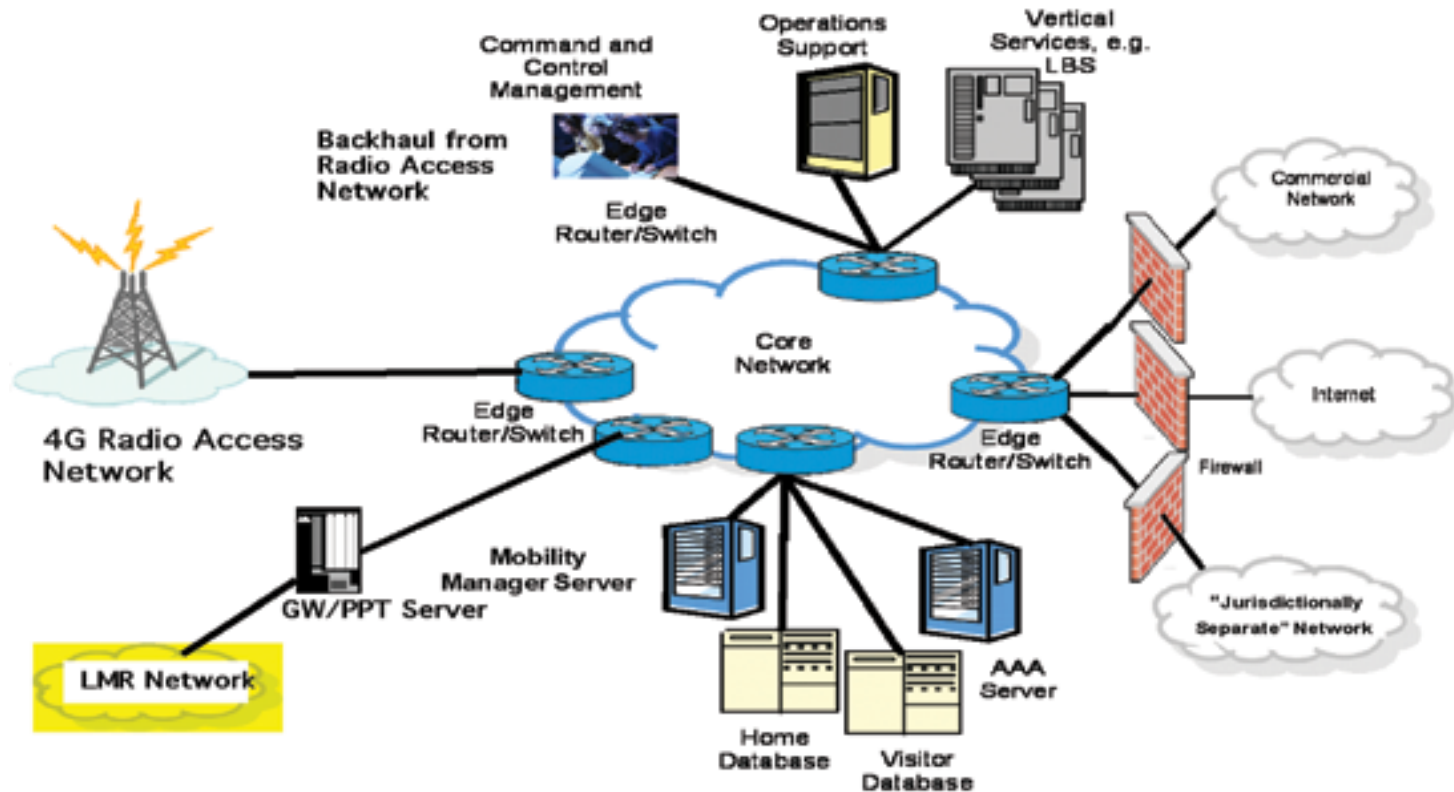
September 4, 2009

FCC's National Broadband Plan

► RECOMMENDATIONS

- Promote public safety wireless broadband communications
 - Create a nationwide interoperable public safety wireless broadband communications network (public safety broadband network).
 - Survey public safety broadband wireless infrastructure and devices.
 - Ensure that broadband satellite service is a part of any emergency preparedness program.
 - Preserve broadband communications during emergencies.

Public Safety Broadband Network Architecture



Interoperability is part of the design

Where do we get the spectrum?

▶ Desired Characteristics:

- More power received → higher the bit rate
 - Function of the Propagation Characteristics
 - Path loss
 - Fading
 - Interference
 - Or more simply → *how much of the transmitted power gets to the receiver ("received power")*
 - Received power decreases proportional to frequency
 - Low frequency signals propagate better than high frequency signals
 - Lower frequency signals have better in-building penetration
- ▶ At 1900 MHz the received power is 90% less than a signal at 700 MHz

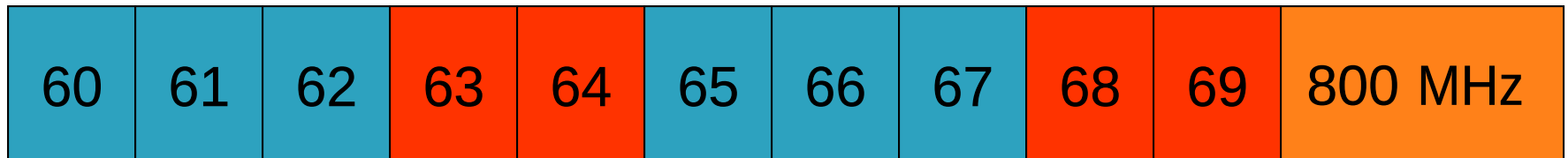


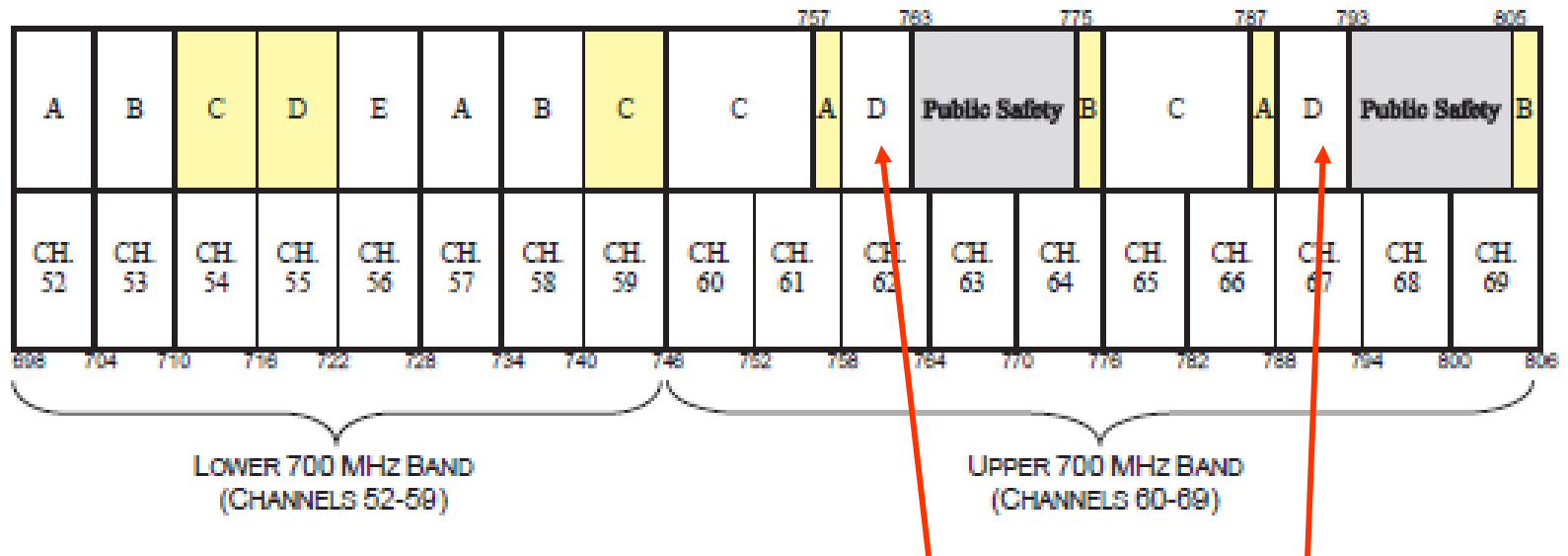
What's at 700 MHz???

700 MHz Spectrum

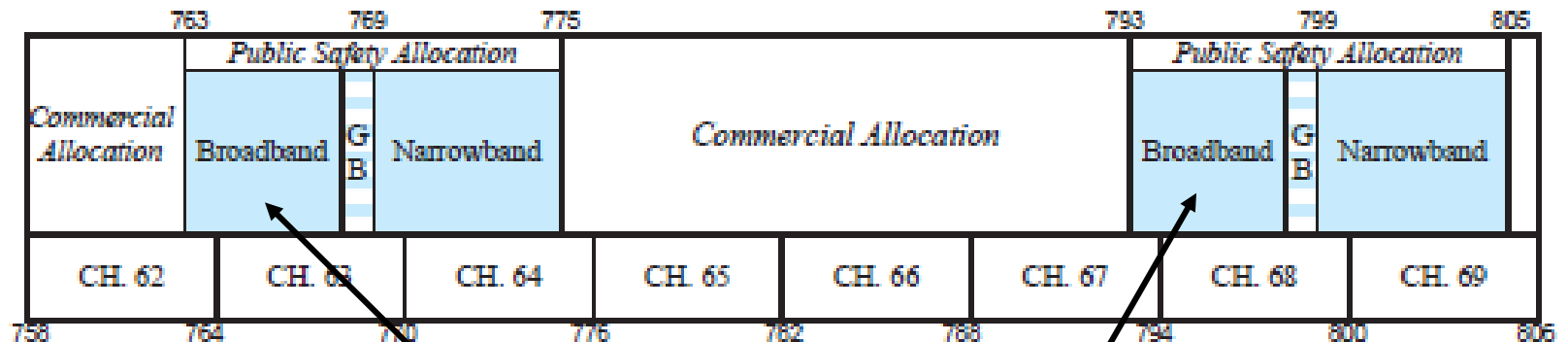
DTV Conversion → TV Broadcasters were required to vacate 700 MHz channels in 2009

700 MHz (TV Channels 60-69)



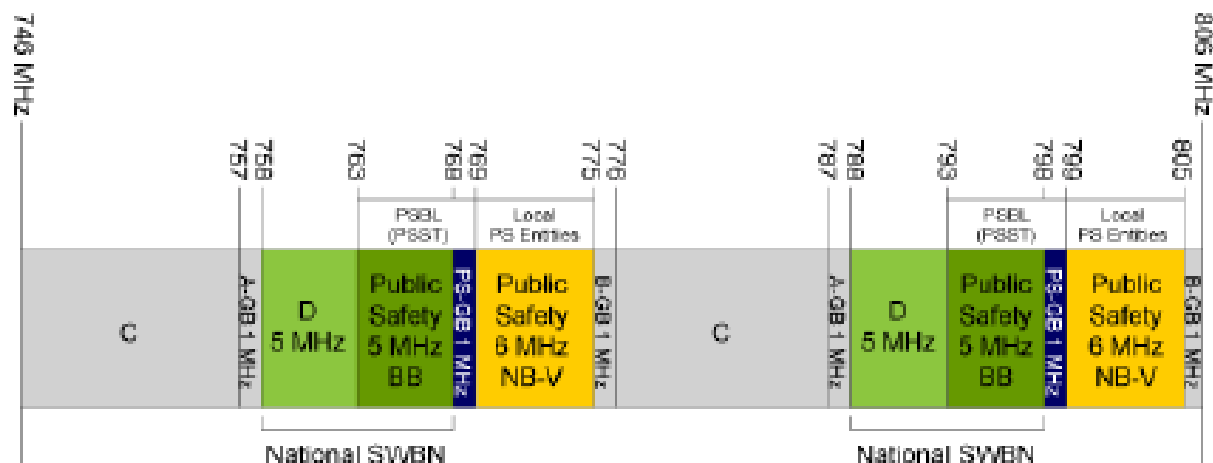


Spectrum To Be Auctioned
With Public Safety Network Requirements
For National Broadband Network



Single
National Public Safety License
For National Broadband Network

Public Safety Spectrum Allocation in the 700 MHz Band



Public Safety 700 MHz Allocations

Total Allocation	(12 x 12)	24 MHz
Broadband Portion	(5 x 5)	10 MHz
Narrowband Portion	(6 x 6)	12 MHz
Guardband Portion	(1 x 1)	2 MHz

Legend

PSBL = Public Safety Broadband Licensee
 PSST = Public Safety Spectrum Trust
 PS Entities = Public Safety Narrowband Licensees
 SWBN = Shared Wireless Broadband Network
 BB = Broadband
 NB-V = Narrowband Voice (e.g., P25 systems)
 PS-GB = Public Safety Guardband

- FCC allocated spectrum to public safety for broadband data services
- Commercial D block, to be combined with public safety broadband allocation

NIST 700MHz Band Channel Propagation Model Videos

<http://www.nist.gov/itl/antd/emntg/700mhz.cfm>

The Vision

Solution for Reliable, High Coverage Mission Critical Voice, Data, & Video 4G Services

**Deployable Equipment
Caches**

For exceptional times and places when PS & commercial infrastructure is insufficient

**DAS and Microcell Systems
In-Building/Underground Coverage**

Coverage deep inside large buildings and capacity for high pedestrian density (e.g., shopping centers) can only be provided by in-building solutions

**Commercial Wireless Networks
Roaming and Priority Access**

Provides access to additional capacity during emergencies, as well as increased network resiliency

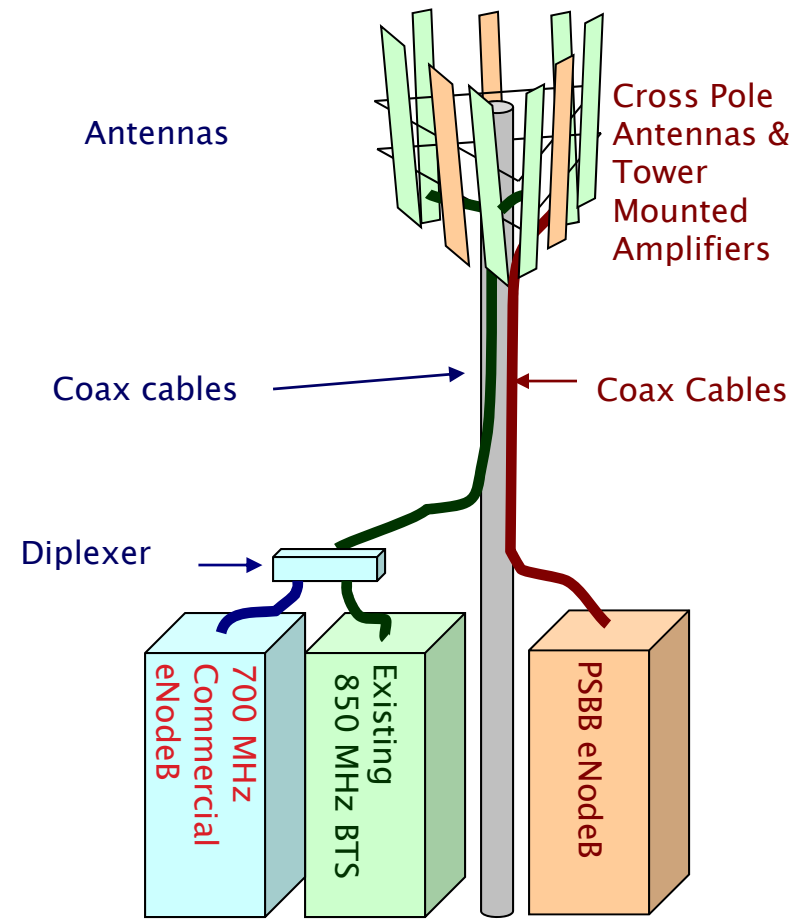
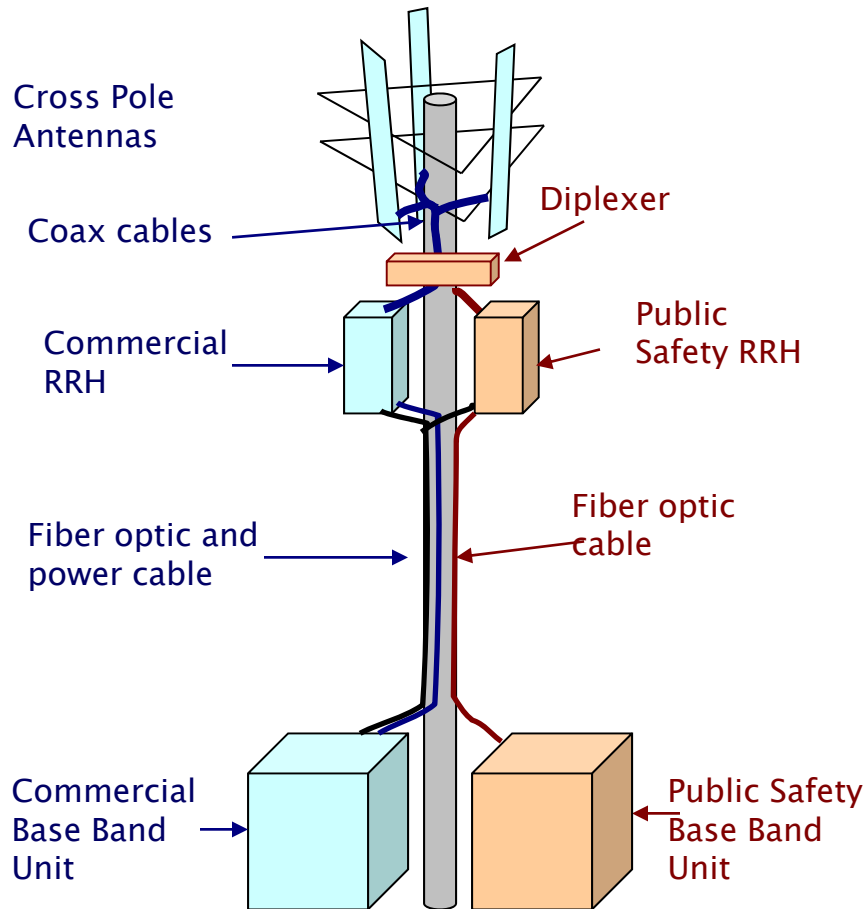
**Public Safety Broadband Wireless Network
Public Safety's Dedicated Network**

Enables high coverage communications, resilient coverage and guaranteed access

The Vision

- ▶ Overlay the Commercial LTE Network to 95% of the Population
 - 41,000 cell towers to achieve the capacity demanded by 290 million subscribers
 - Public safety can use and harden these same towers to achieve excellent coverage and signal reliability for a much smaller number of users
 - Public safety transceivers will be placed on up to 41 K commercial towers.
 - Providers will compete to provide this service
 - Public safety mobile devices will be hardened versions of commercial handheld devices to reduce costs and increase functionality
- ▶ For the most rural remaining 5% build a vehicular LTE network
 - Public safety will use and harden LMR or other towers where available, and will supplement with new towers where needed
 - To reduce number of rural towers needed, mobile devices in rural areas will have externally mounted antennas as is common today
 - In-door coverage improved through “relays” placed in emergency vehicles

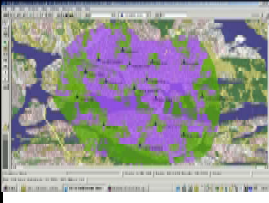
The Vision



What is LTE?

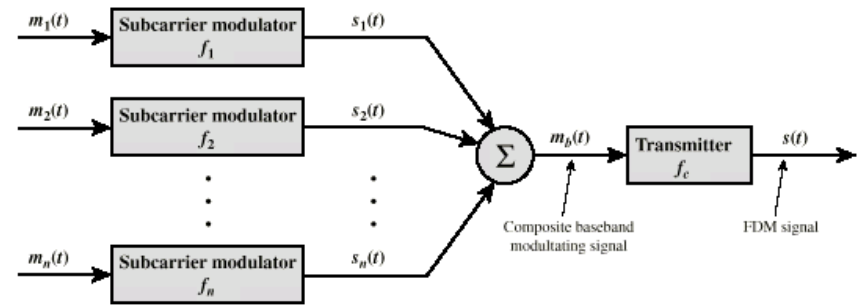
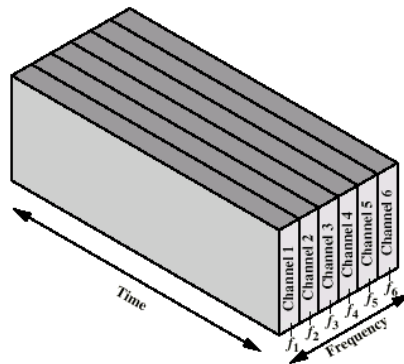
- ▶ Long Term Evolution
 - 4G Cellular
- ▶ Speed....
 - Downlink rates 10 to 300 Mbps
 - Peak 326.4 Mbps for 4x4 MIMO antennas
 - Uplink rates 5 to 75 Mbps
 - Peak 86.4 Mbps for every 20MHz using a single antenna
- ▶ Low latency
 - <100ms from idle to active
 - <5ms for small packets
- ▶ Flexible channel bandwidths
 - 1.4MHz to 20MHz
- ▶ High spectral efficiency (“bits/Hertz”)
- ▶ At least 200 active users in every 5 MHz cell

LTE Targets

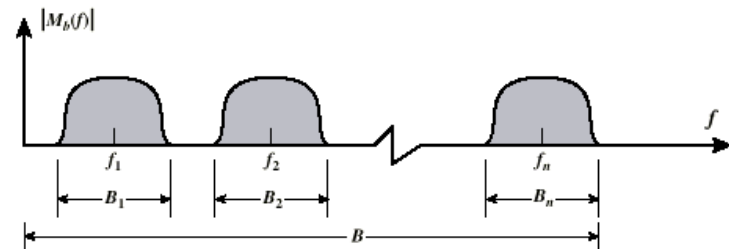
High Data Rates at High Speed		Bit rates: 50(UL), 100Mbps (DL) Speed: Walking to bullet-train
Reduced Cost / Byte		Higher system capacity Lower cost/Byte
Reduced Latency		Quick response time, short RTT, low lag
Optimized for packet-switching		Better support for VoIP & data Greater control of QoS
Cost Efficient Roll-out		Reuse 3G/2G spectrum Bandwidth flexibility Minimum Frequency planning

FDM

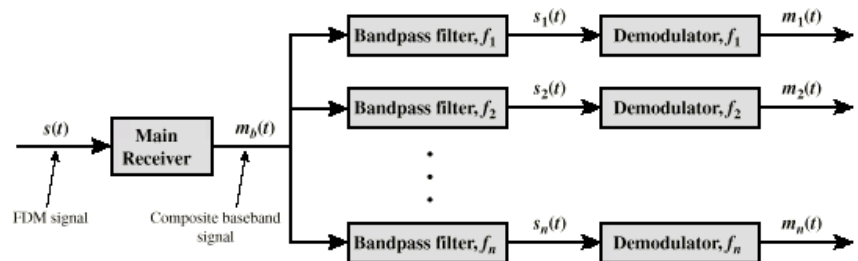
- Frequency-division multiplexing
 - Multiple signals, or carriers, are sent simultaneously over different frequencies between two points



(a) Transmitter



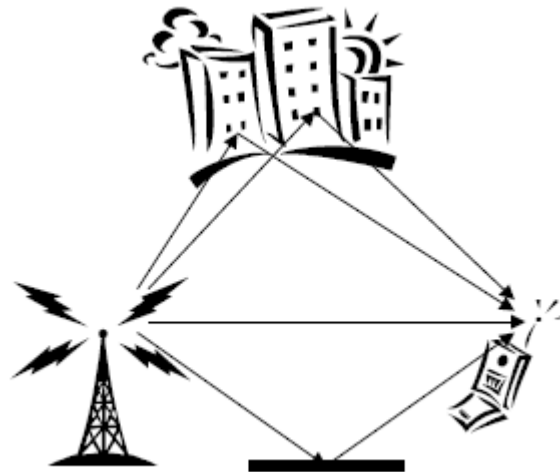
(b) Spectrum of composite baseband modulating signal



(c) Receiver

Problem with FDM ...

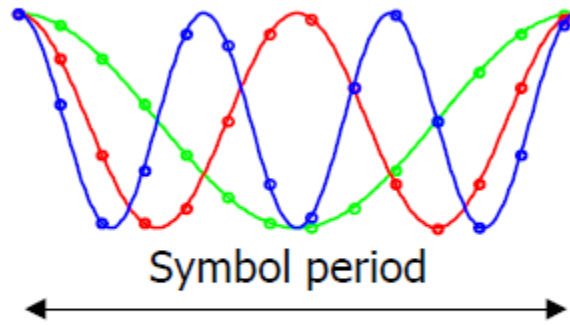
- ▶ FDM has an inherent problem
 - Multi-path → Wireless signals can travel multiple paths from transmitter to receiver (by bouncing off buildings, mountains and even passing airplanes)
 - Receivers can have trouble sorting all the resulting data out



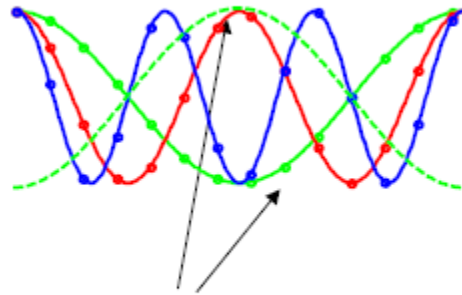
OFDM

- ▶ Orthogonal Frequency Division Multiplexing
 - Allows more information to be carried over a wireless network
 - Wide channels → more resistant to fading
 - Resistant to multi-path
- ▶ “Orthogonal” means non-interfering with each other
 - This makes it possible for multiple channels to operate within close frequency levels without impacting any of the data transmitted in any one channel

First three subcarriers



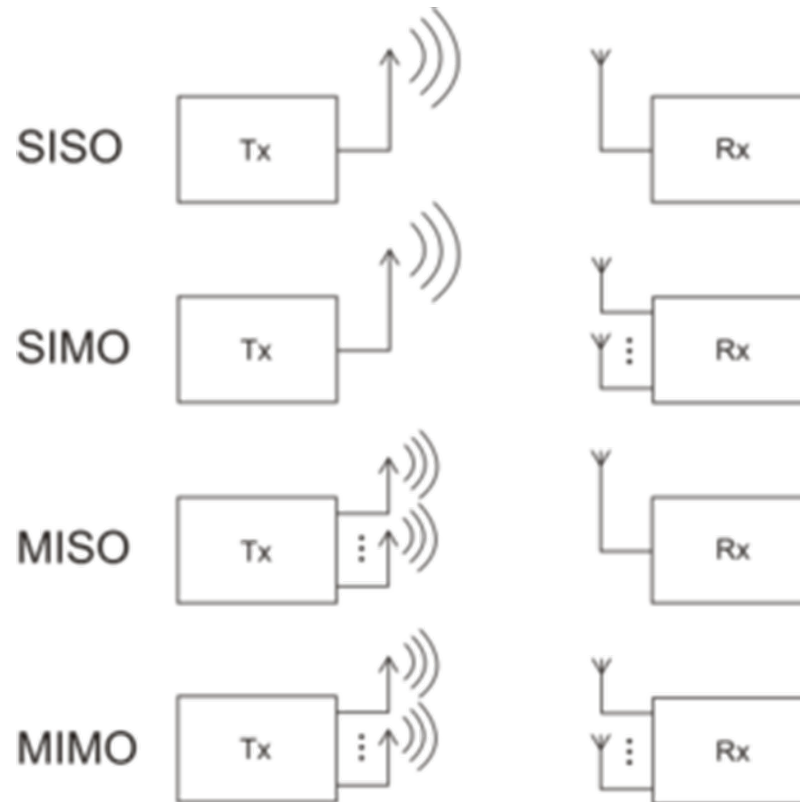
$$\int_0^T \sin \frac{2\pi kt}{T} \sin \frac{-2\pi lt}{T} dt = 0, \quad k \neq l$$



Two possible subcarrier values

- Each subcarrier has a different frequency
- Frequencies chosen so that an integral number of cycles in a symbol period
- Signals are mathematically orthogonal
- Data is carried by varying the phase or amplitude of each subcarrier
- QPSK, 4-QAM, 16-QAM, 64-QAM

Channel Access Modes



Transmit Diversity

Receive Diversity

Multiple Stream

Why different channel access modes?

- ▶ MISO → increases robustness of signal to poor channel conditions
 - No impact to data rates
 - Increases coverage → increases cell capacity
- ▶ SIMO → improves received SNR by combining multiple copies of the same signal
- ▶ MIMO → uses multiple data streams to increase cell capacity
 - Can also allocate multiple data streams to a single user to increase data rates

MIMO in LTE

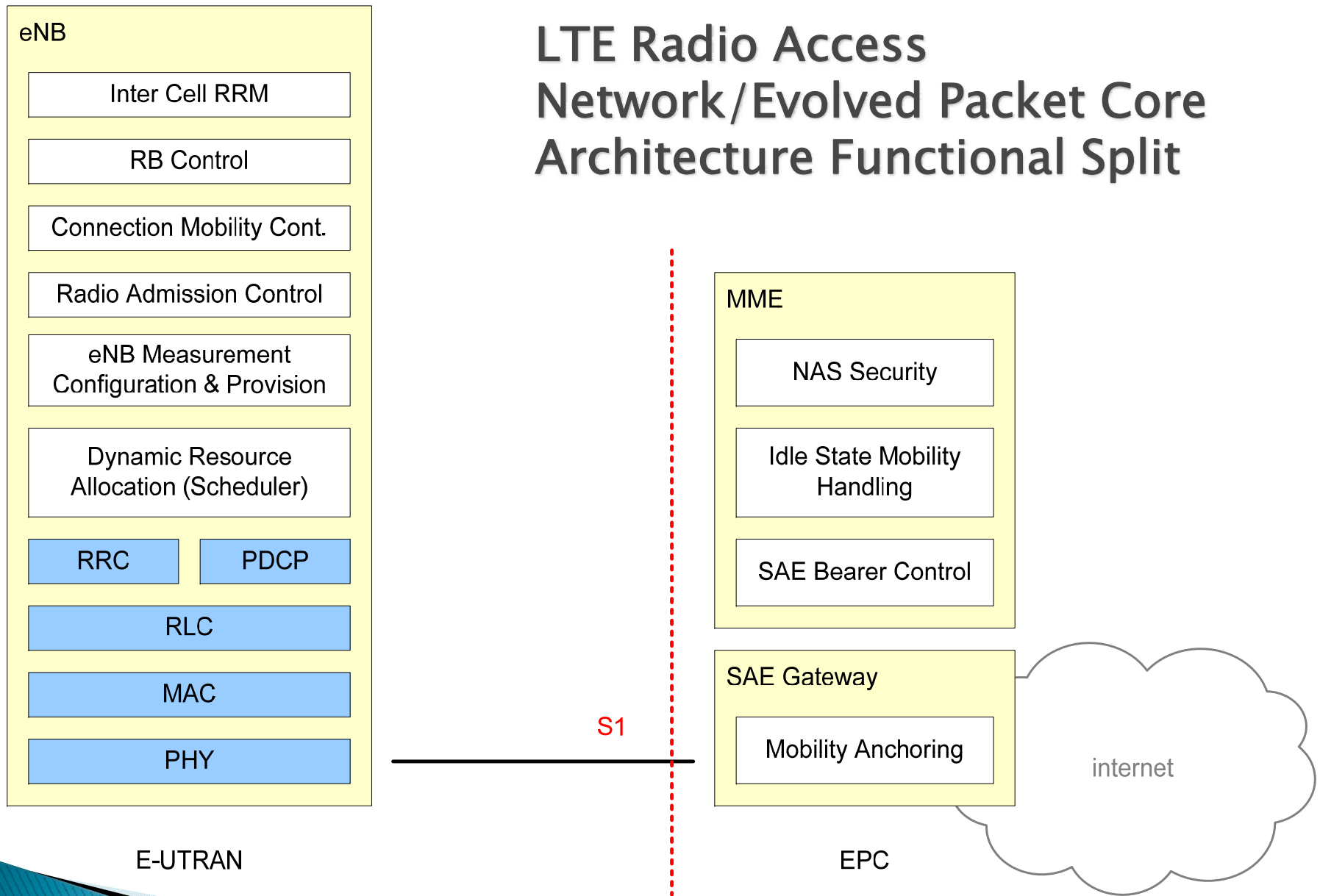
Single data stream / user

- Beamforming
 - Coverage, longer battery life
- Spatial Division Multiple Access (SDMA)
 - Multiple users in same radio resource

Multiple data stream / user

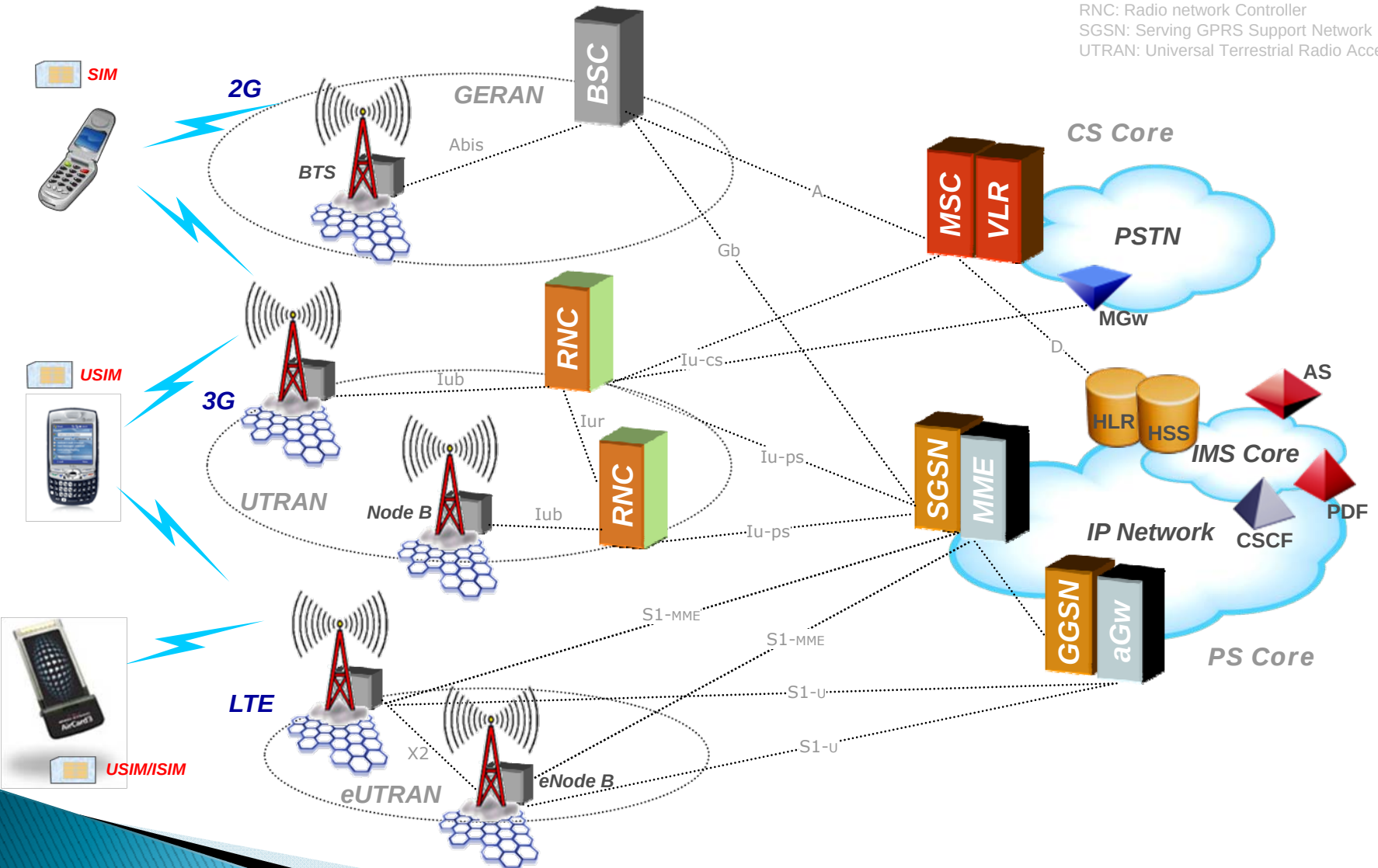
- Diversity
 - Link robustness
- Spatial multiplexing
 - Spectral efficiency, high data rate support

LTE Radio Access Network/Evolved Packet Core Architecture Functional Split



Wireless Simplified Network Architecture

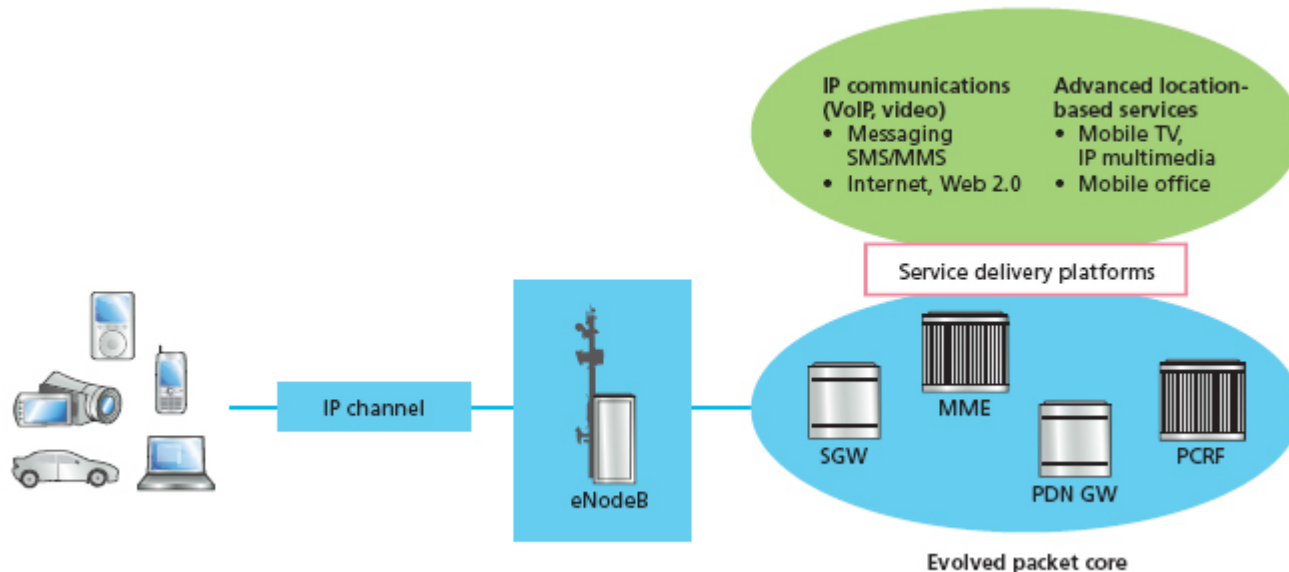
BSC: Base Station Controller
 BTS: Base Transceiver Station
 HLR: Home Location Register
 GERAN: GSM EDGE Radio Access Network
 GGSN: Gateway GPRS Support Network
 LTE: Long Term Evolution
 MSC: Mobile Switching Center
 RNC: Radio network Controller
 SGSN: Serving GPRS Support Network
 UTRAN: Universal Terrestrial Radio Access Network



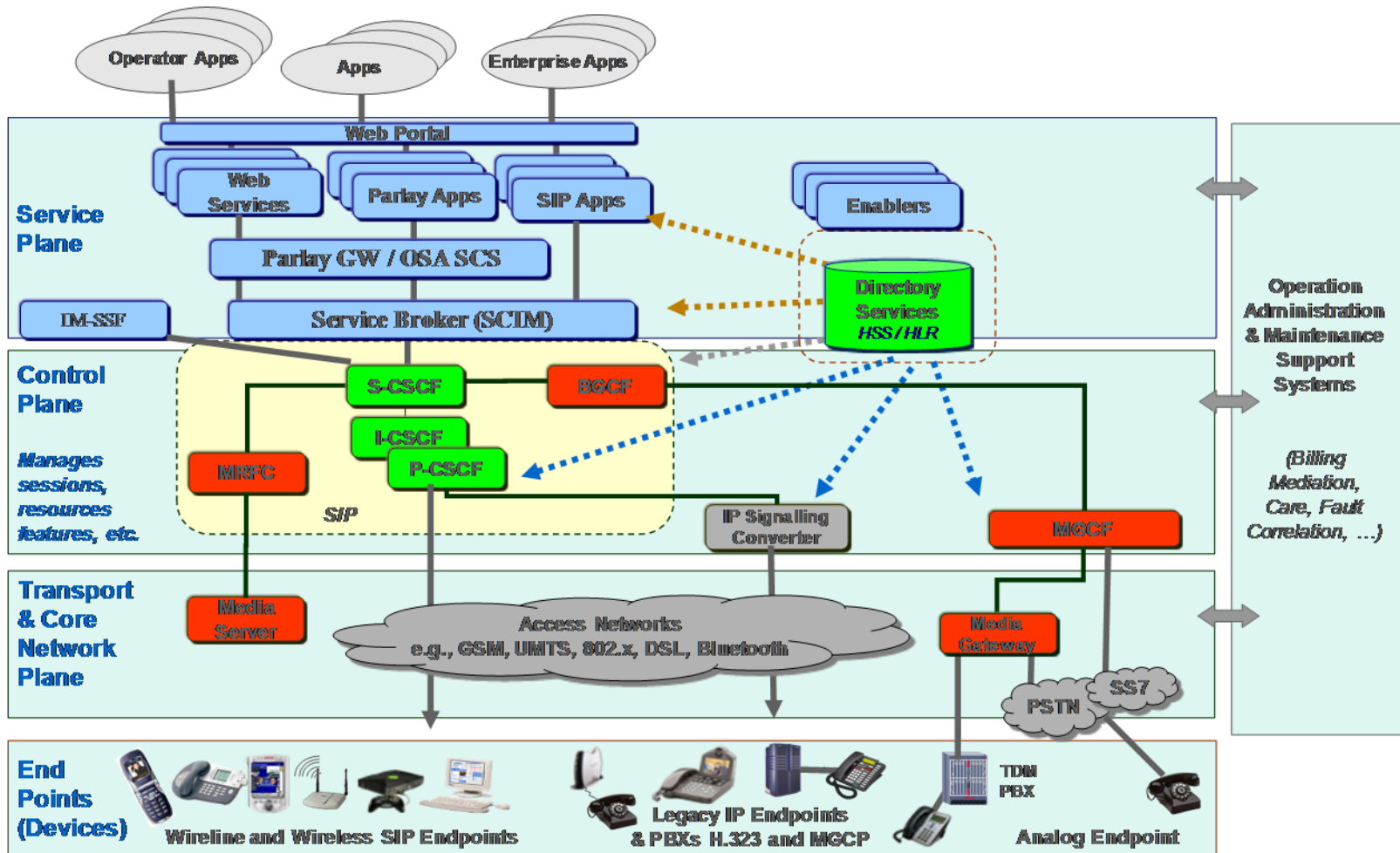
Evolution to All-IP

- ▶ The Evolved Packet Core is an all-IP network
 - All services – including voice – are IP based

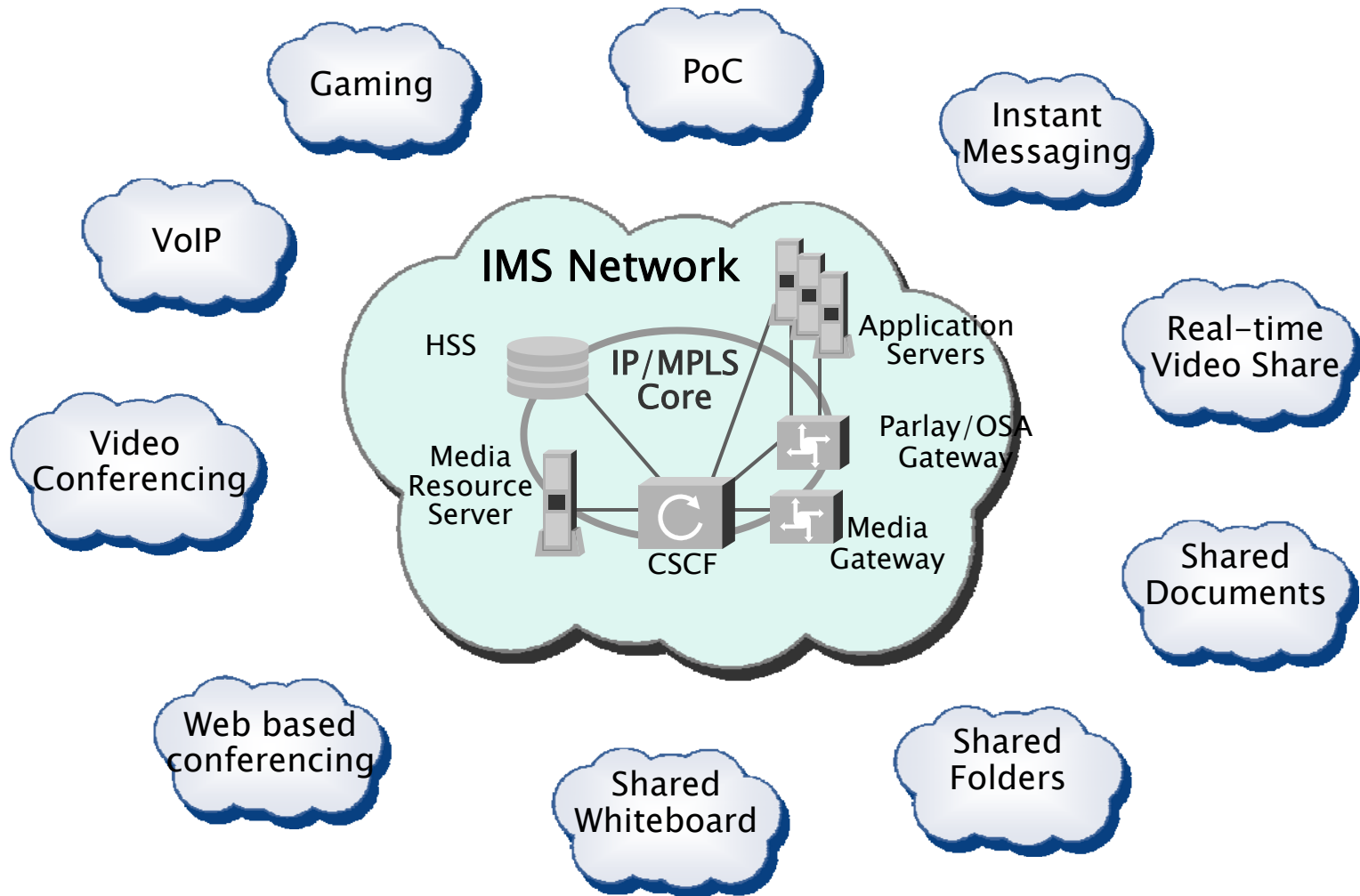
Figure 2. Evolved Packet Core – All-IP core for LTE



IP Multimedia Subsystem



IMS Enables Rich Services



Public Safety Requirements

- ▶ Mission Critical Communications →
 - Hardening of cell sites
 - Extended power outages → battery backup, generators
 - Re-fueling plan
 - Redundant backhaul
 - Alarming on critical sites
 - Antenna & towers designed to handle 15% greater than the Maximum Basic Wind Speed for the structure's location
 - Physical diversity for communications & power
 - Redundancy
 - Priority & Pre-emption

Public Safety Requirements

► Interoperability

- Interface to Project 25 Inter RF Subsystem Interface (ISSI) & Console Subsystem Interface (CSSI) Voice Service and Supplementary Services
- Interface to the PSTN & Cellular Voice Networks
- Support Push to Talk (such as Push-to-talk Over Cellular)
- Interface to the Next Generation 9-1-1
- Interface to a non-terrestrial or satellite based broadband network
- Support connections between the nationwide broadband network, local area broadband systems and local, state or regional voice and data systems

Public Safety Requirements

Application/Service	Description	Data Rate ⁷
File transfer	i.e. to download such items as high-resolution images, GIS data, etc.	Greater than 256kb/s
Email		Less than 16kb/s
Web browsing		Greater than 32kb/s
Cellular voice	Analogous to today's cellular system capability.	4-25 kb/s
Push to talk voice	Analogous to commercial offerings, but coupled with group call capability.	4-25 kb/s
Indoor video	Indoor video is video that is transmitted from inside a building, whether it is surveillance or tactical video.	20-384 kb/s ⁸
Outdoor video	Outdoor video is video that is transmitted from the street, whether it is surveillance or tactical video.	32-384 kb/s ⁸
Location services	This includes location services for personnel as well as vehicles and other objects that public safety tracks.	Less than 16kb/s
Database transactions	This includes both remote databases (data that is not under the agency's direct control), as well as databases that are local.	Less than 32kb/s
Messaging	Instant messaging and SMS type services, both one-way and two-way.	Less than 16kb/s
Operations data	This is a catch all for data that deals with the operations and maintenance of the network, i.e. over the air programming, remote client management, etc.	Less than 32kb/s
Dispatch data	This area primarily covers data as it relates to computer aided dispatching.	Less than 64kb/s

Application/Service	Description	Data Rate ⁷
Generic traffic	This is a catch all for traffic that doesn't fall within any of the categories described above, and that generates less than 64kb of data per second.	Less than 64kb/s
Telemetry	Remote measurement and reporting of information for radio devices, vehicles, etc. Also includes sensors data such as passive chemical detection. Additionally, biometric sensors that require better network performance are also included in this application class.	Less than 32kb/s
Virtual Private Networking		Less than 64kb/s

Public Safety Requirements

▶ Security

- Network shall require each device that attempts to connect to the network to prove its identity prior to granting access to network resources
- Protect against both malicious devices and malicious network stations
 - Authentication must be mutual, with the device proving its identity to the network and the network proving its identity to the device
- Network shall provide cryptographic controls to ensure that transmissions can only be decoded by the intended recipient
 - This must include data encryption over all wireless links

Application: In 1998 many common devices were in their infancy...

Analog cell phones were still widely used



Casio's new digital camera featured 1024 x 768 resolution

The most prevalent internet connection was a 56kbps dial-up modem



The Powerbook G3 had a 300Mhz processor, zip drive and a 5.0 GB hard drive.

Wi-Fi was still in its infancy



Stacked hard drives afforded computer users ample space to store files.

The Walkman combined the ability to listen to tapes and the radio on-the-go.



The first commercial bluetooth products began coming out only in 1998.

Sony released their concept flat-screen model TV in 1998.



DVDs were beginning to overtake VHS tapes but many families began purchasing dual-mode players.



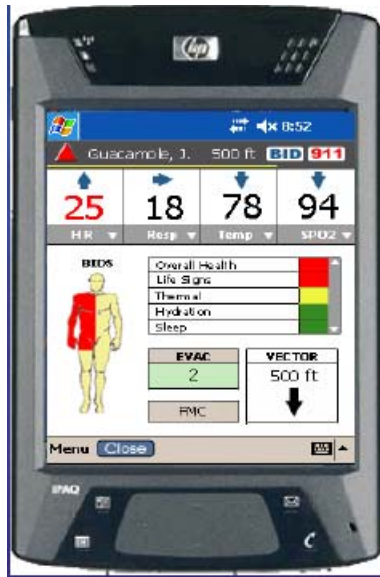
GPS products were still in their infancy.

...all of which are now incorporated into one device



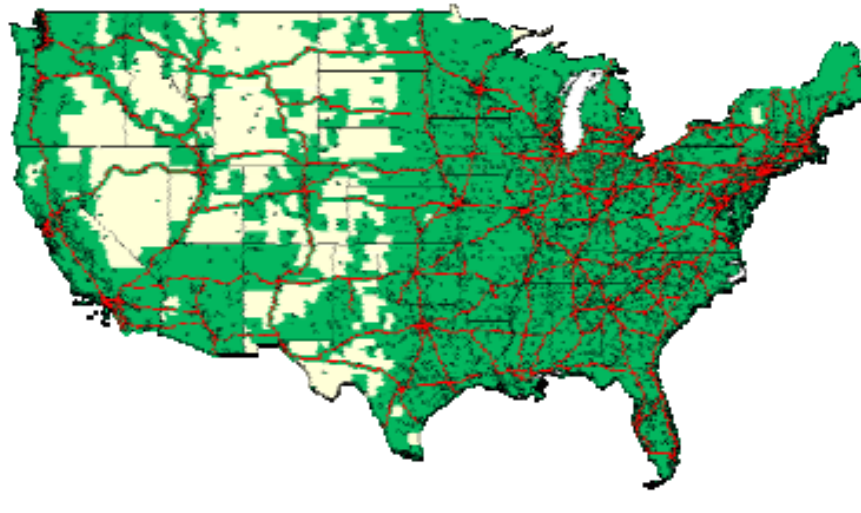
Source: Analysys Mason and industry reports

700 MHz Devices



When?

Terrestrial Coverage* of Public Safety Network in 2019



- 99.3% Population
- 73.5% CONUS Land Mass
- 63% US Land Mass
- All counties w/ population > 5 per sq. mile
- Satellite coverage in "white spaces"

Ongoing Efforts

- ▶ D Block Auction
- ▶ Public Safety 700-MHz Broadband Demonstration Network
 - U.S. Department of Commerce Public Safety Communications Research (PSCR) is implementing a Public Safety Broadband Demonstration Network to provide manufacturers a location for early deployment and evaluation of their systems in a multi-vendor environment
 - Inaugural stakeholder meeting taking place April 20–21, 2010 in Boulder, CO
- ▶ Commercial Mobile Operators Leveraged Services

Questions??